FORM PTO-1390 (Modified) (REV 11-98) U.S. DEPARTMENT OF COMMERCE PATENT AND TRADEMARK OFFICE

TRANSMITTAL LETTER TO THE UNITED STATES DESIGNATED/ELECTED OFFICE (DO/EO/US) CONCERNING A FILING UNDER 35 U.S.C. 371

ATTORNEY'S DOCKET NUMBER
1127 JC16 Rec'd PCT/PTO SEP 24 2001

U.S. APPLICATION NO. (IF KNOWN, SEE 37 CFR
09/937294

INTERNATIONAL APPLICATION NO.	INTERNATIONAL FILING DATE	PRIORITY DATE CLAIMED
PCT/DE00/00661	**02 March 2000**	**24 March 1999**

TITLE OF INVENTION
SYSTEM FOR CHANNEL-ASSOCIATED DISPERSION COMPENSATION OF A WAVELENGTH-DIVISION MULTIPLEX SIGNAL

APPLICANT(S) FOR DO/EO/US
Peter Krummrich

Applicant herewith submits to the United States Designated/Elected Office (DO/EO/US) the following items and other information:

1. ☒ This is a **FIRST** submission of items concerning a filing under 35 U.S.C. 371.
2. ☐ This is a **SECOND** or **SUBSEQUENT** submission of items concerning a filing under 35 U.S.C. 371.
3. ☒ This is an express request to begin national examination procedures (35 U.S.C. 371(f)) at any time rather than delay examination until the expiration of the applicable time limit set in 35 U.S.C. 371(b) and PCT Articles 22 and 39(1).
4. ☒ A proper Demand for International Preliminary Examination was made by the 19th month from the earliest claimed priority date.
5. ☒ A copy of the International Application as filed (35 U.S.C. 371 (c) (2))
   a. ☒ is transmitted herewith (required only if not transmitted by the International Bureau).
   b. ☐ has been transmitted by the International Bureau.
   c. ☐ is not required, as the application was filed in the United States Receiving Office (RO/US).
6. ☒ A translation of the International Application into English (35 U.S.C. 371(c)(2)).
7. ☐ A copy of the International Search Report (PCT/ISA/210).
8. ☒ Amendments to the claims of the International Application under PCT Article 19 (35 U.S.C. 371 (c)(3))
   a. ☒ are transmitted herewith (required only if not transmitted by the International Bureau).
   b. ☐ have been transmitted by the International Bureau.
   c. ☐ have not been made; however, the time limit for making such amendments has NOT expired.
   d. ☐ have not been made and will not be made.
9. ☒ A translation of the amendments to the claims under PCT Article 19 (35 U.S.C. 371(c)(3)).
10. ☒ An oath or declaration of the inventor(s) (35 U.S.C. 371 (c)(4)).
11. ☒ A copy of the International Preliminary Examination Report (PCT/IPEA/409).
12. ☐ A translation of the annexes to the International Preliminary Examination Report under PCT Article 36 (35 U.S.C. 371 (c)(5)).

Items 13 to 20 below concern document(s) or information included:

13. ☐ An Information Disclosure Statement under 37 CFR 1.97 and 1.98.
14. ☒ An assignment document for recording. A separate cover sheet in compliance with 37 CFR 3.28 and 3.31 is included.
15. ☒ A **FIRST** preliminary amendment.
16. ☐ A **SECOND** or **SUBSEQUENT** preliminary amendment.
17. ☒ A substitute specification.
18. ☐ A change of power of attorney and/or address letter.
19. ☒ Certificate of Mailing by Express Mail
20. ☒ Other items or information:

Submission of Drawings - Figures 1-2 on two sheets

U.S. APPLICATION NO. (IF KNOWN, SEE 37 CFR 09/937294	INTERNATIONAL APPLICATION NO. PCT/DE00/00661	ATTORNEY'S DOCKET NUMBER 112740-277

21. The following fees are submitted:.

BASIC NATIONAL FEE (37 CFR 1.492 (a) (1) - (5)) :

		CALCULATIONS	PTO USE ONLY
☐ Neither international preliminary examination fee (37 CFR 1.482) nor international search fee (37 CFR 1.445(a)(2) paid to USPTO and International Search Report not prepared by the EPO or JPO	**$1,000.00**		JC16 Rec'd PCT/PTO SEP 24 2001
☒ International preliminary examination fee (37 CFR 1.482) not paid to USPTO but Internation Search Report prepared by the EPO or JPO	**$860.00**		
☐ International preliminary examination fee (37 CFR 1.482) not paid to USPTO but international search fee (37 CFR 1.445(a)(2)) paid to USPTO	**$710.00**		
☐ International preliminary examination fee paid to USPTO (37 CFR 1.482) but all claims did not satisfy provisions of PCT Article 33(1)-(4)	**$690.00**		
☐ International preliminary examination fee paid to USPTO (37 CFR 1.482) and all claims satisfied provisions of PCT Article 33(1)-(4)	**$100.00**		
ENTER APPROPRIATE BASIC FEE AMOUNT =		**$860.00**	
Surcharge of **$130.00** for furnishing the oath or declaration later than ☐ 20 ☐ 30 months from the earliest claimed priority date (37 CFR 1.492 (e)).		**$0.00**	

CLAIMS	NUMBER FILED	NUMBER EXTRA	RATE		
Total claims	9 - 20 =	0	x $18.00	**$0.00**	
Independent claims	1 - 3 =	0	x $80.00	**$0.00**	
Multiple Dependent Claims (**check if applicable**).			☐	**$0.00**	
TOTAL OF ABOVE CALCULATIONS =				**$860.00**	
Reduction of 1/2 for filing by small entity, if applicable. Verified Small Entity Statement must also be filed (Note 37 CFR 1.9, 1.27, 1.28) **(check if applicable)**.			☐	**$0.00**	
SUBTOTAL =				**$860.00**	
Processing fee of **$130.00** for furnishing the English translation later than ☐ 20 ☐ 30 months from the earliest claimed priority date (37 CFR 1.492 (f)). +				**$0.00**	
TOTAL NATIONAL FEE =				**$860.00**	
Fee for recording the enclosed assignment (37 CFR 1.21(h)). The assignment must be accompanied by an appropriate cover sheet (37 CFR 3.28, 3.31) **(check if applicable)**.			☐	**$0.00**	
TOTAL FEES ENCLOSED =				**$860.00**	
				Amount to be: refunded	$
				charged	$

☒ A check in the amount of **$860.00** to cover the above fees is enclosed.

☐ Please charge my Deposit Account No. in the amount of to cover the above fees. A duplicate copy of this sheet is enclosed.

☒ The Commissioner is hereby authorized to charge any fees which may be required, or credit any overpayment to Deposit Account No. **02-1818** A duplicate copy of this sheet is enclosed.

NOTE: Where an appropriate time limit under 37 CFR 1.494 or 1.495 has not been met, a petition to revive (37 CFR 1.137(a) or (b)) must be filed and granted to restore the application to pending status.

SEND ALL CORRESPONDENCE TO:

William E. Vaughan (Reg. No. 39,056)
Bell, Boyd & Lloyd LLC
P.O. Box 1135
Chicago, Illinois 60690

SIGNATURE

William E. Vaughan
NAME

39,056
REGISTRATION NUMBER

September 24, 2001
DATE

BOX PCT

IN THE UNITED STATES ELECTED/DESIGNATED OFFICE
OF THE UNITED STATES PATENT AND TRADEMARK OFFICE
UNDER THE PATENT COOPERATION TREATY-CHAPTER II

PRELIMINARY AMENDMENT

APPLICANT:	Peter Krummrich	DOCKET NO: 112740-277
SERIAL NO:		GROUP ART UNIT:
		EXAMINER:
INTERNATIONAL APPLICATION NO:		PCT/DE00/00661
INTERNATIONAL FILING DATE:		02 March 2000
INVENTION:	SYSTEM FOR CHANNEL-ASSOCIATED DISPERSION COMPENSATION OF A WAVELENGTH-DIVISION MULTIPLEX SIGNAL	

Assistant Commissioner for Patents,
Washington, D.C. 20231

Sir:

Please amend the above-identified International Application before entry into the National stage before the U.S. Patent and Trademark Office under 35 U.S.C. §371 as follows:

In the Specification:

Please replace the Specification of the present application, including the Abstract, with the following Substitute Specification:

SPECIFICATION

TITLE OF THE INVENTION

SYSTEM FOR CHANNEL-ASSOCIATED DISPERSION COMPENSATION OF A WAVELENGTH-DIVISION MULTIPLEX SIGNAL

BACKGROUND OF THE INVENTION

The present invention relates to a system for the channel-associated dispersion compensation of a wavelength-division multiplex signal wherein the signal is split into individual channel signals which are individually compensated.

In optical transmission systems with high data rates, the necessity to compensate for the distortion of the data signal caused by the dispersion of the transmission fiber frequently arises in the case of relatively long transmission links. At a data rate of 10 Gbit/s, for example, the transmission length will not significantly exceed 100 km with standard monomode fibers without compensation due to the dispersion. In single-channel systems, the dispersion compensation can be carried out in accordance with the dispersion occurring. In the case of wavelength-division multiplex (WDM) systems, however, different dispersion values occur, as a rule, for the individual channel wavelengths. In the ideal case, individual dispersion compensation should be performed for each channel.

Standard solutions for dispersion compensation of WDM signals are shown in Figure 1. Firstly, a precompensation is performed jointly for all WDM channels via a dispersion-compensating fiber DCF0. After a received WDM signal Sλ1-8 has been split into individual part-compensated channels or signals STλ1-STλ8 via a wavelength division (WDM) demultiplexer 2, the remaining compensation is performed, for example, by a dispersion-compensating fiber DCF1 which is connected to the output of the WDM demultiplexer 2. In a variant, a circulator 4 with a half-length dispersion-compensating fiber DCF1/2 is used at the end of which a reflector R is arranged.

The dispersion-compensating fibers have greater dispersion than the transmission fiber but with a different sign, the length being the same. As a rule, a particular dispersion-compensating fiber will only result in the precise compensation of one transmission channel; i.e., the other channels affected are not optimally compensated. Although it is attempted to design the dispersion-compensating fibers in accordance with the transmission fiber, this will only meet with limited success in most cases since it is not possible to adjust arbitrary

variations of the dispersion in dependence on the wavelength and, on the other hand, the transmission fibers used also exhibit component spread.

In implemented systems, therefore, the dispersion tolerance range of the receivers must be designed in most cases to be wide enough for them to be able to detect faultlessly even signals in inadequately compensated channels. If the residual dispersion values of the individual channels deviate from one another to a greater extent, however, this considerably narrows the tolerance range.

Furthermore, additional signal distortion due to non-linear effects of the transmission fiber can narrow the tolerance range. The main disadvantage of the possibilities described above consists in that they are not practical for real use since individual compensation is difficult to carry out.

A further variant also uses a circulator 5 to the center terminal of which, in each case, a chirped (non-uniform) fiber grating 6 is connected. These fiber gratings are supplied with particular dispersion values which still can be changed slightly by mechanical tensioning. A significant disadvantage of the chirped fiber gratings consists in their fluctuations of the phase response. These fluctuations lead to additional signal distortions which can largely ruin the advantages of the channel-selective dispersion compensation again.

From DE 196 02 433 A1, one of the aforementioned compensation devices is known in which an optical precompensation is initially effected, then a splitting of the frequencies into individual channels occurs which are fine-compensated also by dispersion-compensating fibers.

EP 0 884 867 A2 describes methods for signal processing in which optical transversal filters are used. From this patent application it is also known to use dispersion-compensating fibers and also Bragg filters.

In US patent 5,430,568, a cable television system is described in which, in each case, a number of analog television channels are transmitted via different transmission bands. The frequencies of the transmission bands are split for chromatic dispersion compensation and a component is initially compensated optically and then electrically. For the electrical compensation, the component is

initially split electrically into a number of components, one of which is delayed and at least two of which are influenced in compensation networks. This arrangement does not appear to be suitable for compensating digital signals.

It is an object of the present invention to specify a system for dispersion compensation which provides for channel-associated adaptation with little expenditure.

SUMMARY OF THE INVENTION

Accordingly, in an embodiment of the present invention, a system is provided for channel-associated dispersion compensation of a digital wavelength-division multiplex signal, in which the signal is split into individual channel signals which are individually compensated, the system including: a common optical dispersion compensator to which the wavelength-division signal is supplied, the common optical dispersion compensator outputting a part compensated wavelength-division multiplex signal; a wavelength division demultiplexer to which the part compensated wavelength-division multiplex signal is supplied, the demultiplexer splitting the part compensated wavelength-division multiplex signal into individual part-compensated channel signals for output at outputs of the demultiplexer; and an optical electrical converter and subsequent filter for residual compensation connected to each of the outputs of the demultiplexer, wherein compensated signals are output at outputs of the filters.

In an embodiment, the optical electrical converters convert the part-compensated channel signals into electrical digital signals which are supplied to digital filters.

In an embodiment, the optical electrical converters convert the part-compensated channel signals into electrical analog signals which are supplied to filters formed from analog components.

In an embodiment, the filters are second-order filters.

In an embodiment, a dispersion-compensating fiber is provided as the common optical dispersion compensator.

In an embodiment, a wide-band chirped fiber grading is provided as the common optical dispersion compensator.

In yet another embodiment, the common optical dispersion compensator effects a slight under-compensation of the individual channel signals.

Additional features and advantages of the present invention are described in, and will be apparent from, the following Detailed Description of the Invention and the Figures.

BRIEF DESCRIPTION OF THE FIGURES

Figure 1 shows known solutions for dispersion compensation of wavelength-division multiplex signals.

Figure 2 shows an exemplary embodiment of the system for channel-associated dispersion compensation of a wavelength-division multiplex signal of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

An example embodiment of the present invention is explained in greater detail with reference to Figure 2.

A dispersion-compensating fiber DCF0 through which the WDM signal $S\lambda 1$-8 passes is connected to an optical transmission fiber 1. The dispersion-compensating fiber (a wide-band chirped fiber grating also can be used) is dimensioned, for example, in such a manner that at least most of the WDM channels or channel signals SK1-SK8, respectively, are slightly under-compensated. This precompensated WDM signal $ST\lambda 1$-8 is supplied to a wavelength-division demultiplexer 2 which operates as filter for the individual channels or channel signals, respectively, and outputs each of the part-compensated signals $ST\lambda 1$-$ST\lambda 8$ at a separate output. The individual signals are converted into analog or digital electrical signals in converters W1-W8 and are, in each case, supplied to a filter F1-F8. If optimum compensation has already taken place in one of the channels in special cases, the filter can be omitted. The filters can be constructed as transversal filters or recursive filters. Transversal filters are

particularly advantageous since these can be optimized even in systems which are in operation.

A second-order transversal filter is generally adequate for satisfactory compensation. The filter coefficients are optimized on the basis of measurements of the signal quality. The compensated signals SKλ1 to SKλ8 are supplied at outputs A1 to A8 - possibly in each case via an amplifier - to a sampling stage or another suitable receiving device.

Although the present invention has been described with reference to specific embodiments, those of skill in the art will recognize that changes may be made thereto without departing from the spirit and the scope of the invention as set forth in the hereafter appended claims.

ABSTRACT OF THE DISCLOSURE

System for channel-associated dispersion compensation of a wavelength-division multiplex signal, wherein in a common dispersion compensator, a part-compensation of the wavelength-division multiplex signal is initially effected~~.~~ and in-a wavelength-division demultiplexer the part-compensated signal is split into individual part-compensated channel signals which are converted into electrical signals and are compensated in filters.

CLAIMS

On page 5 cancel line 1, and substitute the following left-hand justified heading therefor:

CLAIMS

Please cancel claims 1-6, without prejudice, and substitute the following claims therefor:

7. A system for channel-associated dispersion compensation of a digital wavelength-division multiplex signal, in which the signal is split into individual channel signals which are individually compensated, the system comprising:

a common optical dispersion compensator to which the wavelength-division multiplex signal is supplied, the common optical dispersion compensator outputting a part-compensated wavelength-division multiplex signal;

a wavelength-division demulitplexer to which the part compensated wavelength division multiplex signal is supplied, the demultiplexer splitting the part-compensated wavelength-division multiplex signal into individual part-compensated channel signals for output at outputs of the demultiplexer; and

an optical electrical converter and subsequent filter for residual compensation connected to each of the outputs of the demultiplexer wherein compensated signals are output at outputs of the filters.

8. A system for channel-associated dispersion compensation of a digital wavelength-division multiplex signal as claimed in claim 7, wherein the optical electrical converters convert the part-compensated channel signals into electrical digital signals which are supplied to digital filters.

9. A system for channel-associated dispersion compensation of a digital wavelength-division multiplex signal as claimed in claim 7, wherein the optical electrical converters convert the part-compensated channel signals into electrical analog signals which are supplied to filters formed from analog components.

10. A system for channel-associated dispersion compensation of a digital wavelength-division multiplex signal as claimed in claim 8, wherein the filters are second-order filters.

11. A system for channel-associated dispersion compensation of a digital wavelength division multiplex signal as claimed in claim 9, wherein the filters are second-order filters.

12. A system for channel-associated dispersion compensation of a digital wavelength-division multiplex signal as claimed in claim 7, wherein a dispersion-compensating fiber is provided as the common optical dispersion compensator.

13. A system for channel-associated dispersion compensation of a digital wavelength-division multiplex signal as claimed in claim 7, wherein a wide-band chirped fiber grading is provided as the common optical dispersion compensator.

14. A system for channel-associated dispersion compensation of a digital wavelength-division multiplex signal as claimed in claim 12, wherein the common optical dispersion compensator effects a slight under-compensation of the individual channel signals.

15. A system for channel-associated dispersion compensation of a digital wavelength-division multiplex signal as claimed in claim 13, wherein the common optical dispersion compensator effects a slight under-compensation of the individual channel signals.

REMARKS

The amendment makes editorial changes and corrects typographical errors in the specification, which includes the Abstract, in order to conform the specification to the requirements of United States Patent Practice. No new matter is added thereby. Attached hereto is a marked-up version of the changes made to the specification by the present amendment. The attached page is captioned "**Version With Markings To Show Changes Made**".

In addition, the present amendment cancels original claims 1-6 in favor of new claims 7-15. Claims 7-15 have been presented solely because the revisions by red-lining and underlining which would have been necessary in claims 1-6 in order to present those claims in accordance with preferred United States Patent Practice

would have been too extensive, and thus would have been too burdensome. The present amendment is intended for clarification purposes only and not for substantial reasons related to patentability pursuant to 35 U.S.C. §§103, 102, 103 or 112. Indeed, the cancellation of claims 1-6 does not constitute an intent on the part of the Applicants to surrender any of the subject matter of claims 1-6.

Early consideration on the merits is respectfully requested.

Respectfully submitted,

(Reg. No. 39,056)

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Attorneys for Applicants

VERSIONS WITH MARKINGS TO SHOW CHANGES MADE

In The Specification:

The Specification of the present application, including the Abstract, has been amended as follows:

SPECIFICATION

TITLE OF THE INVENTION

SYSTEM FOR CHANNEL-ASSOCIATED DISPERSION COMPENSATION OF A WAVELENGTH-DIVISION MULTIPLEX SIGNAL

BACKGROUND OF THE INVENTION

~~Description~~

~~Arrangement for channel-associated dispersion compensation of a wavelength-division multiplex signal~~

The present invention relates to ~~an arrangement~~ a system for the channel-associated dispersion compensation of a wavelength-division multiplex signal ~~as claimed in the precharacterizing clause of claim 1.~~ wherein the signal is split into individual channel signals which are individually compensated.

In optical transmission systems with high data rates, the necessity to compensate for the distortion of the data signal caused by the dispersion of the transmission fiber frequently arises in the case of relatively long transmission links. At a data rate of 10 Gbit/s, for example, the transmission length will not significantly exceed 100 km with standard monomode fibers without compensation due to the dispersion. In single-channel systems, the dispersion compensation can be carried out in accordance with the dispersion occurring. In the case of wavelength-division multiplex (WDM) systems, however, different dispersion values occur, as a rule, for the individual channel wavelengths. In the ideal case, individual dispersion compensation should be performed for each channel.

Standard solutions for dispersion compensation of WDM signals are shown in Figure 1. Firstly, a precompensation is performed jointly for all WDM channels ~~by means of~~ via a dispersion-compensating fiber DCF0. After a received WDM

signal Sλ1-8 has been split into individual part-compensated channels or signals STλ1-STλ8 ~~by means of~~ via a wavelength division (WDM) demultiplexer 2, the remaining compensation is performed, for example, by a dispersion-compensating fiber DCF1 which is connected to the output of the WDM demultiplexer 2. In a variant, a circulator 4 with a half-length dispersion-compensating fiber DCF1/2 is used at the end of which a reflector R is arranged.

The dispersion-compensating fibers have greater dispersion than the transmission fiber but with a different sign, the length being the same. As a rule, a particular dispersion-compensating fiber will only result in the precise compensation of one transmission channel~~,~~; i.e., the other channels affected are not optimally compensated. Although it is attempted to design the dispersion-compensating fibers in accordance with the transmission fiber, this will only meet with limited success in most cases since it is not possible to adjust arbitrary variations of the dispersion in dependence on the wavelength and, on the other hand, the transmission fibers used also exhibit component spread.

In implemented systems, therefore, the dispersion tolerance range of the receivers must be designed in most cases to be wide enough for them to be able to detect faultlessly even signals in inadequately compensated channels. If the residual dispersion values of the individual channels deviate from one another to a greater extent, however, this considerably narrows the tolerance range.

Furthermore, additional signal distortion due to non-linear effects of the transmission fiber can narrow the tolerance range. The main disadvantage of the possibilities described above consists in that they are ~~practicable only with difficulty~~ not practical for real use since individual compensation is difficult to carry out.

A further variant also uses a circulator 5 to the center terminal of which, in each case, a chirped (non-uniform) fiber grating 6 is connected. These fiber gratings are supplied with particular dispersion values which ~~can~~ still can be changed slightly by mechanical tensioning. A significant disadvantage of the chirped fiber gratings consists in their fluctuations of the phase response. These

fluctuations lead to additional signal distortions which can largely ruin the advantages of the channel-selective dispersion compensation again.

From DE 196 02 433 A1, one of the aforementioned compensation devices is known in which an optical precompensation is initially effected, then a splitting of the frequencies into individual channels occurs which are fine-compensated also by dispersion-compensating fibers.

EP 0 884 867 A2 describes methods for signal processing in which optical transversal filters are used. From this patent application it is also known to use dispersion-compensating fibers and also Bragg filters.

In US patent 5,430,568, a cable television system is described in which, in each case, a number of analog television channels are transmitted via different transmission bands. The frequencies of the transmission bands are split for chromatic dispersion compensation and a component is initially compensated optically and then electrically. For the electrical compensation, the component is initially split electrically into a number of components, one of which is delayed and at least two of which are influenced in compensation networks. This arrangement does not appear to be suitable for compensating digital signals.

It is ~~the~~ an object of the present invention to specify ~~an arrangement~~ a system for dispersion compensation which provides for channel-associated adaptation with little expenditure.

SUMMARY OF THE INVENTION

Accordingly, in an embodiment of the present invention, a system is provided for channel-associated dispersion compensation of a digital wavelength-division multiplex signal, in which the signal is split into individual channel signals which are individually compensated, the system including: a common optical dispersion compensator to which the wavelength-division signal is supplied, the common optical dispersion compensator outputting a part compensated wavelength-division multiplex signal; a wavelength division demultiplexer to which the part compensated wavelength-division multiplex signal is supplied, the demultiplexer splitting the part compensated wavelength-division multiplex signal

into individual part-compensated channel signals for output at outputs of the demultiplexer; and an optical electrical converter and subsequent filter for residual compensation connected to each of the outputs of the demultiplexer, wherein compensated signals are output at outputs of the filters.

In an embodiment, the optical electrical converters convert the part-compensated channel signals into electrical digital signals which are supplied to digital filters.

In an embodiment, the optical electrical converters convert the part-compensated channel signals into electrical analog signals which are supplied to filters formed from analog components.

In an embodiment, the filters are second-order filters.

In an embodiment, a dispersion-compensating fiber is provided as the common optical dispersion compensator.

In an embodiment, a wide-band chirped fiber grading is provided as the common optical dispersion compensator.

In yet another embodiment, the common optical dispersion compensator effects a slight under-compensation of the individual channel signals.

Additional features and advantages of the present invention are described in, and will be apparent from, the following Detailed Description of the Invention and the Figures.

BRIEF DESCRIPTION OF THE FIGURES

Figure 1 shows known solutions for dispersion compensation of wavelength-division multiplex signals.

Figure 2 shows an exemplary embodiment of the system for channel-associated dispersion compensation of a wavelength-division multiplex signal of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

An example embodiment of the present invention is explained in greater detail with reference to Figure 2.

A dispersion-compensating fiber DCF0 through which the WDM signal Sλ1-8 passes is connected to an optical transmission fiber 1. The dispersion-compensating fiber (a wide-band chirped fiber grating ~~can~~ also can be used) is dimensioned, for example, in such a manner that at least most of the WDM channels or channel signals SK1-SK8, respectively, are slightly under-compensated. This precompensated WDM signal STλ1-8 is supplied to a wavelength-division demultiplexer 2 which operates as filter for the individual channels or channel signals, respectively, and outputs each of the part-compensated signals STλ1-STλ8 at a separate output. The individual signals are converted into analog or digital electrical signals in converters W1-W8 and are, in each case, supplied to a filter F1-F8. If optimum compensation has already taken place in one of the channels in special cases, the filter can be omitted. The filters can be constructed as transversal filters or recursive filters. Transversal filters are particularly advantageous since these can be optimized even in systems which are in operation.

A second-order transversal filter is generally adequate for satisfactory compensation. The filter coefficients are optimized on the basis of measurements of the signal quality. The compensated signals SKλ1 to SKλ8 are supplied at outputs A1 to A8 - possibly in each case via an amplifier - to a sampling stage or another suitable receiving device.

Although the present invention has been described with reference to specific embodiments, those of skill in the art will recognize that changes may be made thereto without departing from the spirit and the scope of the invention as set forth in the hereafter appended claims.

ABSTRACT OF THE DISCLOSURE

~~Abstract~~

~~Arrangement~~ System for channel-associated dispersion compensation of a wavelength-division multiplex signal, wherein in ~~In~~ a common dispersion compensator ~~(DCF0)~~, a part-compensation of the wavelength-division multiplex ~~(WDM)~~ signal ~~(Sλ1-8)~~ is initially effected~~.~~ and in ~~In~~ a wavelength-division

demultiplexer ~~2,~~ the part-compensated ~~WDM~~ signal is split into individual part-compensated channel signals ~~(ST1-ST8)~~ which are converted into electrical signals and are compensated in filters ~~(F1 to F8)~~.

~~Figure 2~~

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JC16 Rec'd PCT/PTO SEP 24 2001

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Description

Arrangement for channel-associated dispersion compensation of a wavelength-division multiplex signal

The invention relates to an arrangement for the channel-associated dispersion compensation of a wavelength-division multiplex signal as claimed in the precharacterizing clause of claim 1.

In optical transmission systems with high data rates, the necessity to compensate for the distortion of the data signal caused by the dispersion of the transmission fiber frequently arises in the case of relatively long transmission links. At a data rate of 10 Gbit/s, for example, the transmission length will not significantly exceed 100 km with standard monomode fibers without compensation due to the dispersion. In single-channel systems, the dispersion compensation can be carried out in accordance with the dispersion occurring. In the case of wavelength-division multiplex (WDM) systems, however, different dispersion values occur, as a rule, for the individual channel wavelengths. In the ideal case, individual dispersion compensation should be performed for each channel.

Standard solutions for dispersion compensation of WDM signals are shown in Figure 1. Firstly, a precompensation is performed jointly for all WDM channels by means of a dispersion-compensating fiber DCF0. After a received WDM signal Sλ1-8 has been split into individual part-compensated channels or signals STλ1-STλ8 by means of a wavelength division (WDM) demultiplexer 2, the remaining compensation is performed, for example, by a dispersion-compensating fiber DCF1 which is connected to the output of the WDM demultiplexer 2. In a variant, a circulator 4 with a

half-length dispersion-compensating fiber DCF1/2 is used at the end of which a reflector R is arranged. The dispersion-compensating fibers have greater dispersion than the transmission fiber but with a different sign, the length being the same. As a rule, a particular dispersion-compensating fiber will only result in the precise compensation of one transmission channel, i.e. the other channels affected are not optimally compensated. Although it is attempted to design the dispersion-compensating fibers in accordance with the transmission fiber, this will only meet with limited success in most cases since it is not possible to adjust arbitrary variations of the dispersion in dependence on the wavelength and, on the other hand, the transmission fibers used also exhibit component spread.

In implemented systems, therefore, the dispersion tolerance range of the receivers must be designed in most cases to be wide enough for them to be able to detect faultlessly even signals in inadequately compensated channels. If the residual dispersion values of the individual channels deviate from one another to a greater extent, however, this considerably narrows the tolerance range.

Furthermore, additional signal distortion due to non-linear effects of the transmission fiber can narrow the tolerance range. The main disadvantage of the possibilities described above consists in that they are practicable only with difficulty for real use since individual compensation is difficult to carry out.

A further variant also uses a circulator 5 to the center terminal of which in each case a chirped (non-uniform) fiber grating 6 is connected. These fiber gratings are supplied with particular dispersion values which can still be changed slightly by mechanical

tensioning. A significant disadvantage of the chirped fiber gratings consists in their fluctuations of the phase response. These fluctuations lead to additional signal distortions which can largely ruin the advantages of the channel-selective dispersion compensation again.

It is the object of the invention to specify an arrangement for dispersion compensation which provides for channel-associated adaptation with little expenditure.

An example embodiment of the invention is explained in greater detail with reference to Figure 2.

A dispersion-compensating fiber DCF0 through which the WDM signal Sλ1-8 passes is connected to an optical transmission fiber 1. The dispersion-compensating fiber (a wide-band chirped fiber grating can also be used) is dimensioned, for example, in such a manner that at least most of the WDM channels or channel signals SK1-SK8, respectively, are slightly under-compensated. This precompensated WDM signal STλ1-8 is supplied to a wavelength-division demultiplexer 2 which operates as filter for the individual channels or channel signals, respectively, and outputs each of the part-compensated signals STλ1-STλ8 at a separate output. The individual signals are converted into analog or digital electrical signals in converters W1-W8 and are in each case supplied to a filter F1-F8. If optimum compensation has already taken place in one of the channels in special cases, the filter can be omitted. The filters can be constructed as transversal filters or recursive filters. Transversal filters are particularly advantageous since these can be optimized even in systems which are in operation.

A second-order transversal filter is generally adequate for satisfactory compensation. The filter coefficients are optimized on the basis of measurements of the signal quality. The compensated signals SKλ1 to SKλ8 are supplied at outputs A1 to A8 - possibly in each case via an amplifier - to a sampling stage or another suitable receiving device.

Patent claims

1. An arrangement for the channel-associated dispersion compensation of a wavelength-division multiplex (WDM) signal, in which this signal is split into individual channel signals (SK1 to SK8) which are individually compensated,
characterized in that a common dispersion compensator (DCF0) is provided which is supplied with the WDM signal (Sλ1-8),
in that a wavelength-division demultiplexer (2) is provided which is supplied with the WDM signal part-compensated in this manner (STλ1-8), which is split into individual part-compensated channel signals (STλ1 to STλ8),
in that in each case an optoelectrical converter (W1 to W8) and a subsequent filter (F1 to F8) for residual compensation is connected to the outputs of the wavelength-division demultiplexer (2), so that
that compensated signals (SKλ1 to SKλ8) are output at outputs (A1 to A8) of the filters.

2. The arrangement as claimed in claim 1, characterized in that electrooptical converters (W1, W8) are provided which convert the part-compensated channel signals (STλ1 to STλ8) into electrical digital signals which are supplied to digital filters (F1, F8).

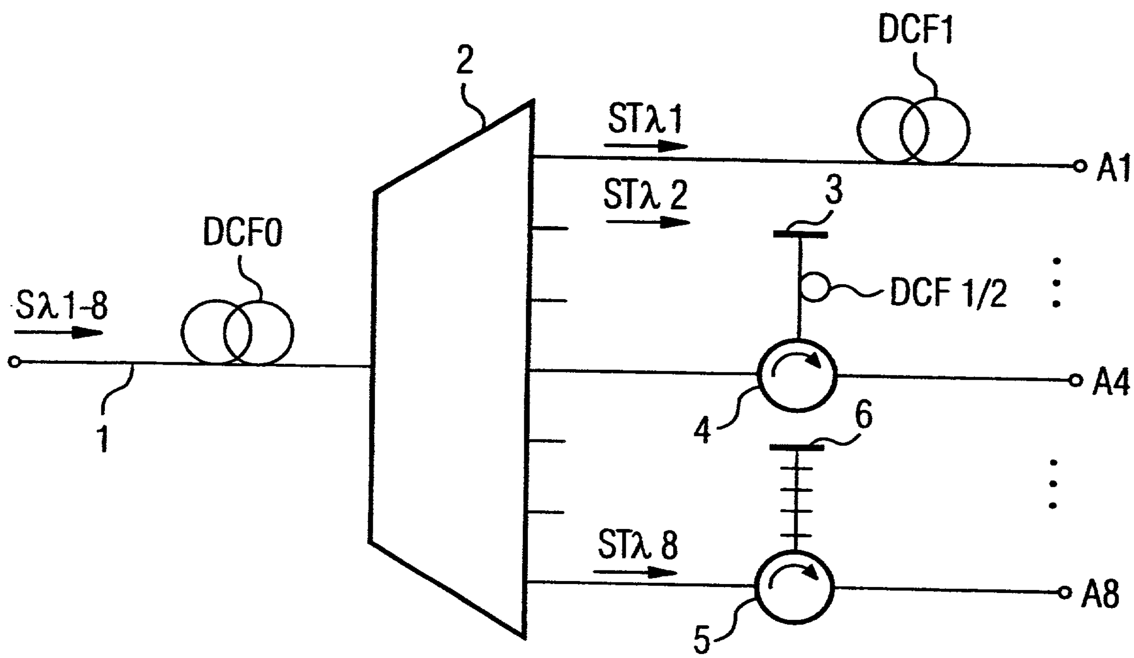
3. The arrangement as claimed in claim 1, characterized in that electrooptical converters (W4) are provided which convert the part-compensated channel signals (STλ1 to STλ8) into electrical analog signals which are supplied to filters (F4) implemented by means of analog components.

4. The arrangement as claimed in claim 2 or 3, characterized in that second-order filters (F1 to F8) are provided.

5. The arrangement as claimed in one of the preceding claims, characterized in that a dispersion-compensating fiber or a wide-band chirped fiber grating is provided as the common dispersion compensator (DCF0).

6. The arrangement as claimed in claim 5, characterized in that a common dispersion compensator (DCF0) is provided which causes a slight under-compensation of the of the individual channel signals.

FIG 1



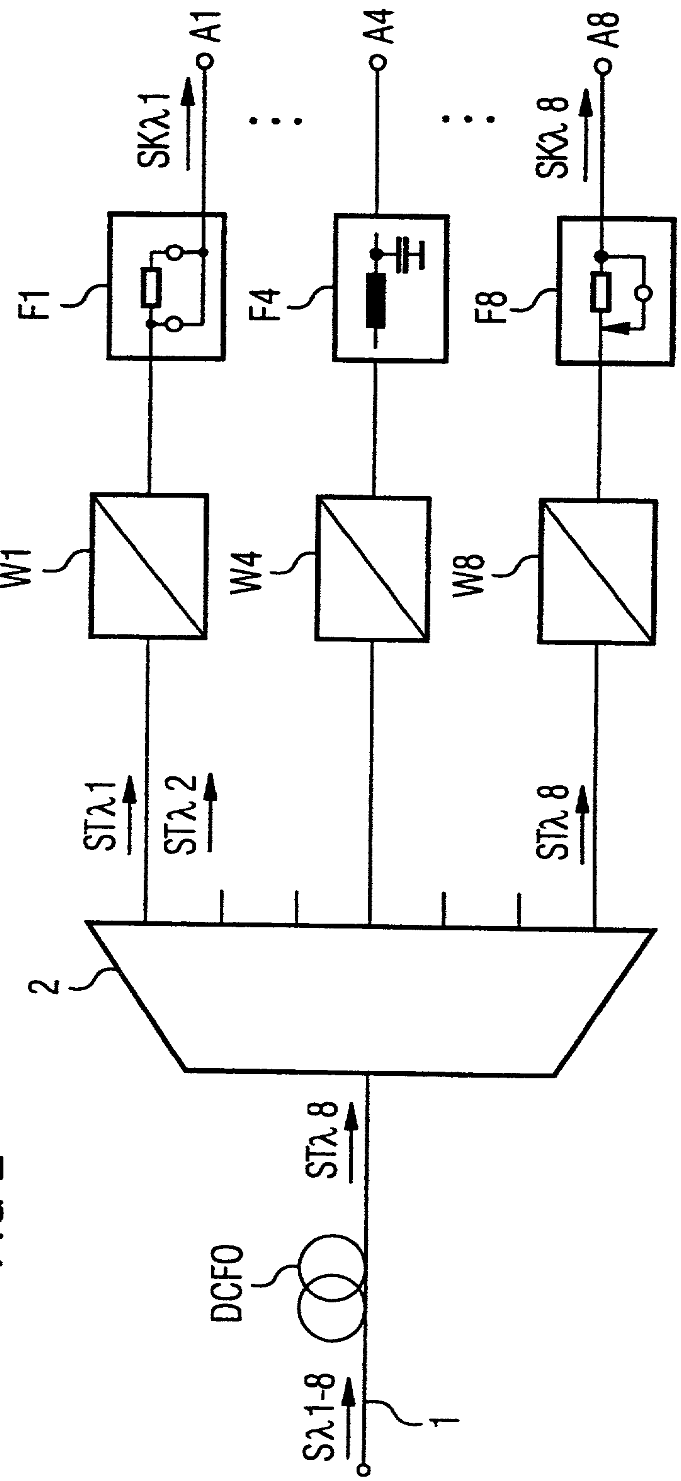

A1
A4
A8
SKλ1
SKλ 8
F1
F4
F8
W1
W4
W8
STλ1
STλ 2
STλ 8
2
STλ 8
DCFO
Sλ1-8
1

FIG 2

Declaration and Power of Attorney For Patent Application
Erklärung Für Patentanmeldungen Mit Vollmacht
German Language Declaration

Als nachstehend benannter Erfinder erkläre ich hiermit an Eides Statt:

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dass ich, nach bestem Wissen der ursprüngliche, erste und alleinige Erfinder (falls nachstehend nur ein Name angegeben ist) oder ein ursprünglicher, erster und Miterfinder (falls nachstehend mehrere Namen aufgeführt sind) des Gegenstandes bin, für den dieser Antrag gestellt wird und für den ein Patent beantragt wird für die Erfindung mit dem Titel:

Anordnung zur kanalindividuellen Dispersionskompensation eines Wellenlaengen-Multiplexsignals

deren Beschreibung

(zutreffendes ankreuzen)
☐ hier beigefügt ist.
☒ am 02.03.2000 als
PCT internationale Anmeldung
PCT Anmeldungsnummer PCT/DE00/00661
eingereicht wurde und am ________
abgeändert wurde (falls tatsächlich abgeändert).

Ich bestätige hiermit, dass ich den Inhalt der obigen Patentanmeldung einschliesslich der Ansprüche durchgesehen und verstanden habe, die eventuell durch einen Zusatzantrag wie oben erwähnt abgeändert wurde.

Ich erkenne meine Pflicht zur Offenbarung irgendwelcher Informationen, die für die Prüfung der vorliegenden Anmeldung in Einklang mit Absatz 37, Bundesgesetzbuch, Paragraph 1.56(a) von Wichtigkeit sind, an.

Ich beanspruche hiermit ausländische Prioritätsvorteile gemäss Abschnitt 35 der Zivilprozessordnung der Vereinigten Staaten, Paragraph 119 aller unten angegebenen Auslandsanmeldungen für ein Patent oder eine Erfindersurkunde, und habe auch alle Auslandsanmeldungen für ein Patent oder eine Erfindersurkunde nachstehend gekennzeichnet, die ein Anmeldedatum haben, das vor dem Anmeldedatum der Anmeldung liegt, für die Priorität beansprucht wird.

As a below named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated below next to my name,

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled

Device for channel-specific dispersion compensation of a wavelength multiplex signal

the specification of which

(check one)
☐ is attached hereto.
☒ was filed on 02.03.2000 as
PCT international application
PCT Application No. PCT/DE00/00661
and was amended on ________
(if applicable)

I hereby state that I have reviewed and understand the contents of the above identified specification, including the claims as amended by any amendment referred to above.

I acknowledge the duty to disclose information which is material to the examination of this application in accordance with Title 37, Code of Federal Regulations, §1.56(a).

I hereby claim foreign priority benefits under Title 35, United States Code, §119 of any foreign application(s) for patent or inventor's certificate listed below and have also identified below any foreign application for patent or inventor's certificate having a filing date before that of the application on which priority is claimed:

Form PTO-FB-240 (8-83)
Patent and Trademark Office-U.S. DEPARTMENT OF COMMERCE
IDNR: 2590 / V: 99-1.00 / B:Val

German Language Declaration

Prior foreign appplications
Priorität beansprucht

Priority Claimed

19913374.3 (Number) (Nummer)	DE (Country) (Land)	24.03.1999 (Day Month Year Filed) (Tag Monat Jahr eingereicht)	☒ Yes Ja	☐ No Nein
(Number) (Nummer)	(Country) (Land)	(Day Month Year Filed) (Tag Monat Jahr eingereicht)	☐ Yes Ja	☐ No Nein
(Number) (Nummer)	(Country) (Land)	(Day Month Year Filed) (Tag Monat Jahr eingereicht)	☐ Yes Ja	☐ No Nein

Ich beanspruche hiermit gemäss Absatz 35 der Zivilprozessordnung der Vereinigten Staaten, Paragraph 120, den Vorzug aller unten aufgeführten Anmeldungen und falls der Gegenstand aus jedem Anspruch dieser Anmeldung nicht in einer früheren amerikanischen Patentanmeldung laut dem ersten Paragraphen des Absatzes 35 der Zivilprozeßordnung der Vereinigten Staaten, Paragraph 122 offenbart ist, erkenne ich gemäss Absatz 37, Bundesgesetzbuch, Paragraph 1.56(a) meine Pflicht zur Offenbarung von Informationen an, die zwischen dem Anmeldedatum der früheren Anmeldung und dem nationalen oder PCT internationalen Anmeldedatum dieser Anmeldung bekannt geworden sind.

I hereby claim the benefit under Title 35. United States Code. §120 of any United States application(s) listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States application in the manner provided by the first paragraph of Title 35, United States Code, §122, I acknowledge the duty to disclose material information as defined in Title 37, Code of Federal Regulations, §1.56(a) which occured between the filing date of the prior application and the national or PCT international filing date of this application.

PCT/DE00/00661 (Application Serial No.) (Anmeldeseriennummer)	02.03.2000 (Filing Date D, M, Y) (Anmeldedatum T, M, J)	anhängig (Status) (patentiert, anhängig, aufgegeben)	pending (Status) (patented, pending, abandoned)
(Application Serial No.) (Anmeldeseriennummer)	(Filing Date D,M,Y) (Anmeldedatum T, M; J)	(Status) (patentiert, anhängig, aufgeben)	(Status) (patented, pending, abandoned)

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I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true, and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

German Language Declaration

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POWER OF ATTORNEY: As a named inventor, I hereby appoint the following attorney(s) and/or agent(s) to prosecute this application and transact all business in the Patent and Trademark Office connected therewith. *(list name and registration number)*

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81379 MUENCHEN	81379 MUENCHEN

Voller Name des zweiten Miterfinders (falls zutreffend):	Full name of second joint inventor, if any:
Unterschrift des Erfinders — Datum	Second Inventor's signature — Date
Wohnsitz: ,	Residence: ,
Staatsangehörigkeit	Citizenship
Postanschrift	Post Office Address

(Bitte entsprechende Informationen und Unterschriften im Falle von dritten und weiteren Miterfindern angeben).

(Supply similar information and signature for third and subsequent joint inventors).